Designing and Building with Compass and Edge

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Designing and building with compass and edge

My background is several years of designing and building square rule Timber Frames. I recently spent a weekend with Laurie Smith in his beautiful home in Wales, learning about his research into early building design and the geometrical proportions of medieval timber structures.

This article is about my first attempt at using compass geometry in design and layout. It is not an attempt at recreating a historically accurate building process or a historically accurate structure for that matter. It is an investigation in the practical application of geometry. Laurie Smith's book is a very good introduction to the subject and has shown itself to be a very useful aid. We had it at hand for reference throughout the building process and it was leafed through and discussed by several of the students involved in the project.

10 years ago the municipality of Brøndby outside of Copenhagen established an activation project /job training for the long term unemployed, people under rehab, immigrants and others who need a little help to get into the job market. The project is a medieval village with 9 houses situated around a small pond, complete with blacksmith shop, weaving shop, BBQ pit and a stave chapel. They get a steady flow of school children pouring through the village every day, where they make rope, cook over an open fire, fire trebuches, tinsmith and roam around.

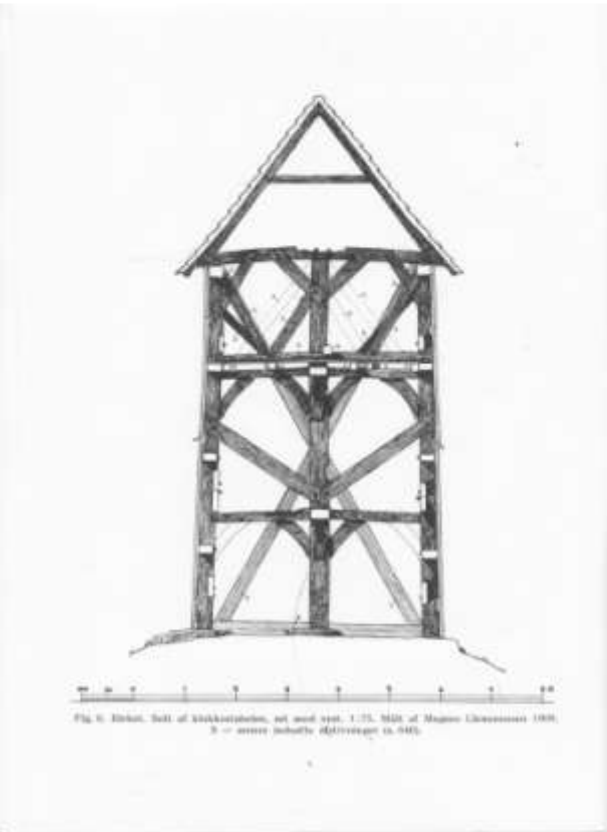
In October 2009 they asked if I could come and build a church steeple and teach their building crew about Timber Framing. The inspiration comes from a church steeple from ca. 1350 in southern Denmark. I didn't have to make an exact copy and I had to use the timbers that they had in stock. At the initial meeting at the site Jens Degerbøl, the manager and daily leader of the village stepped out the size of the steeple. He wanted it to be about 2,5 meters square and 6-7-8 meters high.

I decided to try to use Laurie Smiths ideas of using only straightedge and compass as design and layout tools. In his book the diameter of the daisy wheel is based on a certain rod that a particular leading designer carried around. I wanted to individualize the rod length for this particular project so I asked Jens Degerbøl to hold up his arms. That height is the basic measurement for the entire design, 1 Jens.

The real Jens is a fairly short guy so I didn't feel that his height from head to toes would work as a basic unit. By having him reach up, I got a measurement that was closer to the width of the building, (1 Jens is 228 cm for those who are geometrically impaired).

We cut a length of stick to 1 Jens and used it extensively throughout the entire building process.
I had a theory that since building in medieval times probably was done by builders who were illiterate then this geometrical approach could work with people who are not trained carpenters and who are not comfortable with mathematics. I think they got it. It was lots of fun to hear the crew use phrases like "where is Jens?" "He is leaning up against the corner over there". "There is ½ Jens from there to there and 1 Jens across".

The original tower has two ties dividing it in thirds. That led to the idea of a tower that was 1 Jens wide and 2½ Jens high: Two storeys high plus a plate at railing height. 1 Jens is also a good measurement from floor to floor. The first step was to see if the original steeple had any geometrical proportions that I could copy.
Fortunately I had access to a survey from 1909 made by the architect Clemmensen. The original frame has

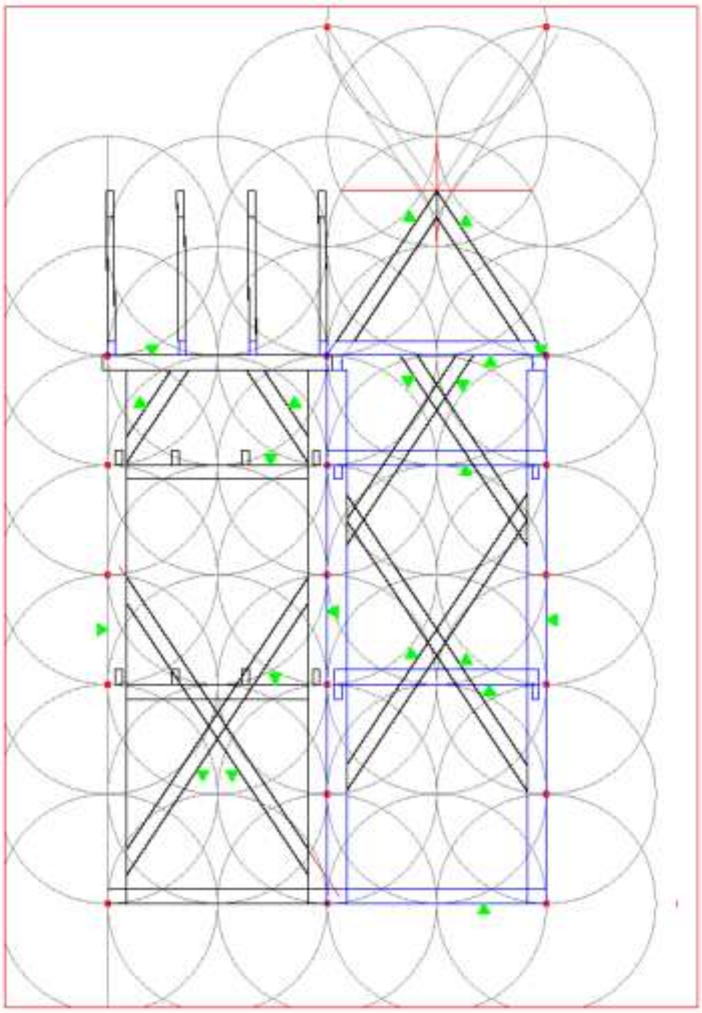


had extensive remodelling done later. The dark timbers are the old framing. The lighter shaded framing with the large X-bracing is later.

I only had about a week to "crack the code" so the analysis was not very thorough.
The steeple is about 1½ times higher than the width. I couldn't find any proportion in the roof slope so I cheated and measured it with a protractor. The slope of the roof is 54^0 That didn't really ring any bells!
I thought the later long diagonal braces looked better than the original short knee braces.
Since the tower is square in plan, it made more sense to work "ad quadratum" than "ad triangulum" [pix]

Having ½ Jens from floor to plate provided a good railing and good room for the bell. 2½ Jens is also just less than 6 meters so I would not waste so much of the 200x200 posts I had available. Stepping ½Jens points up the posts gave some reference points to connect to make the braces.

Around that time the design suddenly “clicked”. Simplicity and repetition became a theme for the design. It made sense as a workshop project to keep things simple and it keeps the system simple. The long X-braces gave a reference back to the design of the original steeple.



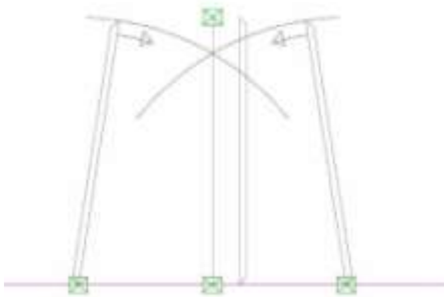
The X-braces cross a rectangle measuring 2 by 3, the ratio of the original tower. So the bracing on the gables is the same as on the sides, just offset ½Jens. The roof slope is defined as the same slope as the X-braces. Just to check, I measured the slope. It is 56^0, very close to the same slope as the original tower.

My preferred sketch tool is 3D AutoCad so I soon switched to the computer for further drawings. I normally develop the design directly in 3D, but here it turned out to be too complicated to move sticks around on a background of circles. My timbers kept on snapping to the wrong points It was simpler to draw the front and side of the tower side by side. It also supported my idea of “wrapping” the braces around the tower.

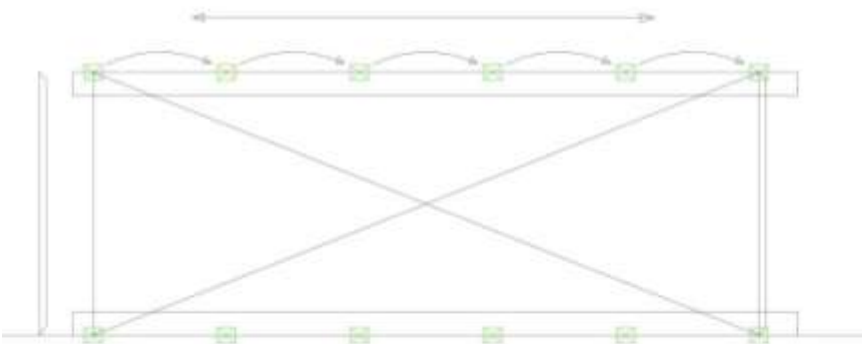
Layout

The whole layout is based on the ½Jens points along the posts so the plan was to first get the posts in position, level and square, then layout a sequence of ½Jens points on the posts and then lay out joists and braces directly on the posts.

I made some square blocks (out of MDF) with an X and 4 holes for nails. A pink nylon string is strung out and 2 blocks are laid out 2½ Jens apart. I let the string run past the blocks and raised a perpendicular by going ½ Jens out to each side, drawing 2 arcs with the Jens stick and pulling a string through the base block and where the arcs cross. (Standard procedure for creating a perpendicular line)



A new base block was placed along the perpendicular, 1 Jens from the other.
That is the width of the tower measured at the base. I did the same at the top of the tower.
Then I placed the second post A2 along the new reference line. So far so good. Just to check, I stepped off



2½ Jens along the edge of the A2 post. And there was ca. 35mm deviance! The method is geometrically dead-on accurate so something must have happened in the practical execution of the layout. One explanation could be that the arcs described to mark the perpendicular point was scratched in the ground with a nail. Not very accurate.

We saved the layout by drawing one perpendicular, placed post A2 roughly parallel to A1, stepped off the post length on A2 and measured across at the top. Then I'll be sure the posts are parallel. To get a rectangle out of the bottom and top reference points, I'll check the diagonals. – as shown on the drawing -. By moving the entire distance laid out on post A2 back and forth until the diagonals are the same, I can create a rectangle on the two posts.

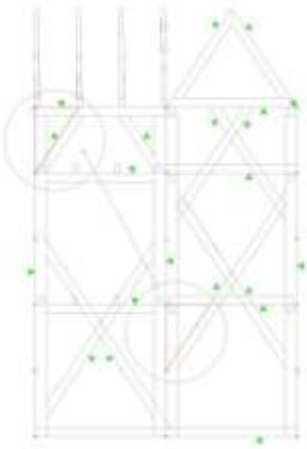
Using a spun nylon string to check a length is really bad because the string is very elastic. I have a good steel band that neatly rolls up into a little fist size steel box that can clip on to a tool belt. That was really good for comparing one diagonal to the other. I promise; I didn't look at the numbers and increments on the tape. I didn't measure. It was a purely geometrical comparison.
With the posts parallel and the diagonals identical, then the 4 points form a rectangle, with 90^0 corners.

Now the perfect rectangle and reference points are laid out on the post timbers instead of on the ground. Joinery was laid out using a plum bob.

It was neat to use the reference points on the posts to layout members that would later go elsewhere in the frame. The trusses were half of an X-brace and was laid out right over an assembled X-brace.
Where the small braces go into the plates is measured further down on the wall and then transferred up to the plate.

The red circle indicates a ½Jens point,
the triangle is a reference side

Joinery:



The Jens unit was used again in some of the joinery. The tenons are 1/24 Jens long. All tenons are flush with one side of a brace or joist. There are no housings and no reductions. There was just one place where that simplicity posed a problem. At the upper level at the gable there are two Xbraces crossing each other very close together. I was afraid that the tenon would shear off behind the lap joint. The solution was to use a lap joint both at the brace-to-brace joint and at the brace-to-post joint. The lapjoint in the post is a copy of the lap found in the barns in Cressing Temple, England and used in the Gardeners Shelter at the same place. (see the book by Laurie Smith about that project) It would have been nice and appropriate to use timbers in 1/12 Jens (190mm) wide, but we had to use what we had at hand so all the braces and joists are 75x150mm douglas fir. And so is the lapjoint. The width of the tenons is 40mm.This is not a sacred number in any regard; it is just practical because my chain mortiser makes 40 mm mortises.

The wonder of power tools: One chain mortiser doing the work of 5 men!

In my original design stopped the upper X-braces at the tie of the gable trusses. When we laid it out on the ground we got the idea to extend them all the way up to connect to the rafters and It looked obvious when the whole thing was assembled.

We had one design glitch that wasn't discovered until the raising day.
How to get the lowest brace tenon in at the same time as the post tenon into the sill mortise? We solved it by leaning the first bent slightly back to raise the brace tenon and pull it away from the post. Then we raised the Bent 2 to plumb but raised out above its mortices. We only had to cut a tiny amount of the brace tenon to get it in place.

The tower is now situated next to the stave chapel in the edge of the village. The original plan was to clad the whole tower with vertical siding to protect it from weather and vandalism. Now they might just clad the first 16’ and expose the upper framing.

Lessons learned
This article is a description of lessons learned and corners cut. The next time will be different.

It is important to keep a sense of scale when designing with the daisywheels.
So I imposed a person icon in my AutoCad drawing as an external reference when I designed. Once in a while I pulled the guy in on my drawing to check if there was enough headroom under the braces or if the plate had an appropriate height to act as a baluster for the top deck.
Using the height of the client as a unit for design and layout was a lot of fun and it worked really well.

Using geometrical design as a teaching tool.
I have had many good experiences in teaching Timber Framing with Square rule layout but the shop drawings have to be very complete and detailed. It can be quite painstaking for the students to approach all those millimeters and decimals at the beginning of a workshop and I have had one student who seized up and aborted the workshop. By using a geometrical layout I needed far fewer numbers and the whole process of laying out reference lines, timbers and joinery had a lot more “organic” feel to it. The language we used reflected this understanding: we said things like: “It is from here to over there”. “This is the same as on the other side” and “This is transferred straight down to flush with the other one”. A common non-verbal understanding of the project arose during the two weeks we spent together.
I hoped to experience a sort of “musical” understanding of the geometry in the design and layout. And it did happen. Several of the design decisions made underway were based on a sense of belonging “within the system”.

Thanks to Laurie Smith for help and advise with the writing of this article.
And for his book: The Gardner’s Shelter at Cressing Temple. Published by the Carpenters Fellowship.